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# SOIL RESISTIVITY TESTS AT BIRCH JUNCTION

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Soil resistivity tests were conducted using the Wenner method at the proposed site for the 115-kV line/cable junction near Birch Ave. The results indicate a multi-layer soil structure at the site. A two-layer interpretation of the test data provides an adequate model for use in design type calculations.

## 1.0 INTRODUCTION

Birch Junction is a new 115-kV line/cable junction located in downtown Toronto close to the Summerhill subway station. The site is located on the wide embankment of Canadian National Railway tracks and is congested with fences, tracks, HV towers, cables, bridges, roads and buildings. Soil resistivity tests were conducted at the site prior to construction for use in the design calculations of the grounding system performance at the junction. The tests were conducted on March 26, 1991 and the project was requested and funded by Transmission Lines Programs Department.

## 2.0 TEST PROCEDURE

The Wenner method /1/ was used to measure the soil resistivity and surveys were done at five selected locations at the site as shown in Figure 1. The railway embankment is approximately 20 m wide and 5 m high. Survey #1 was done on top of the bank about 3 m south of the fence and 5 m north of the tracks and Survey #3 was done on the level ground. A Megger DET-2 ground resistance tester was used to take the Wenner readings. The Megger was calibrated using a 100 Ω resistor and the required correction was applied to the readings. For each probe spacing, a second reading was taken with the test current injection reversed and the average value was used for the analysis. Survey locations and the maximum probe spacing for each survey was limited by the accessibility.

## 3.0 TEST RESULTS

The weather on the test date was sunny and cool (about 13°C) and the soil was moist due to rain during the previous night. All survey locations except in the park were characterized by surface gravel as noted during the tests. Apparent resistivities were calculated from the measured Wenner readings using equation 7.1 of the Grounding Guide /1/. Tables 1 to 4 list the calculated apparent resistivities for each survey location along with the modelled values.

**TABLE 1**
**SOIL RESISTIVITY FROM SURVEY # 1**

| Spacing (m) | Apparent Resistivity (Ω.m) Measured | Modelled (A) | Modelled (B) |
|---|---|---|---|
| 1 | 451 | 450 | 458 |
| 2 | 251 | 270 | 250 |
| 5 | 112 | 112 | 112 |
| 10 | 61 | 100 | - |
| 20 | 39 | 100 | - |
| 50 | 19 | 100 | - |

**TABLE 2**
**SOIL RESISTIVITY FROM SURVEY #2**

| Spacing (m) | Apparent Resistivity (Ω.m) Measured | Modelled |
|---|---|---|
| 1 | 62 | 92 |
| 2 | 68 | 92 |
| 5 | 94 | 92 |
| 10 | 89 | 92 |
| 20 | 28 | 92 |

**TABLE 3**
**SOIL RESISTIVITY FROM SURVEY #3**

| Spacing (m) | Apparent Resistivity (Ω.m) Measured | Modelled (A) | Modelled (B) |
|---|---|---|---|
| 1 | 183 | 183 | 186 |
| 2 | 81 | 81 | 83 |
| 5 | 20 | 35 | - |
| 10 | 32 | 32 | 34 |
| 20 | 38 | 32 | 34 |
| 50 | 30 | 32 | 33 |

**TABLE 4**
**SOIL RESISTIVITY FROM SURVEYS #4 & #5**

| Spacing (m) | Apparent Resistivity (Ω.m) Measured | | | Modelled | |
|---|---|---|---|---|---|
| | Survey 4 | Survey 5 | Avg | (A) | (B) |
| 1 | 390 | 402 | 396 | 350 | 357 |
| 2 | 233 | 299 | 266 | 300 | 311 |
| 5 | 168 | 228 | 198 | 150 | 165 |
| 10 | 85 | 113 | 99 | 100 | 102 |
| 20 | 75 | 97 | 86 | 86 | 92 |
| 50 | 50 | - | 50 | 86 | - |

## 4.0 INTERPRETATION OF TWO-LAYER MODELS

The decreasing resistivities with probe spacings in Surveys 1, 3, 4 and 5 clearly indicate a multi-layer soil structure with more conductive bottom soil at the sites. Separate two-layer models with an upper layer of resistivity $\rho_1$ of thickness d and a second layer of resistivity $\rho_2$ of infinite depth are often considered adequate for grounding system studies. Therefore, a two-layer soil model (A) for each of the test locations was interpreted from the field data using the graphical method described in Appendix D of the Grounding Guide /1/. The average of the measured data

from Surveys 4 and 5 were used to obtain the two-layer model for the location. A physical insight into the plotted data at the locations revealed that some of the Wenner readings may have been influenced by the proximity of the fences and other underground metallic objects in the vicinity. These bad data were filtered out in the interpretation. Also a two-layer model (B) for each test location was obtained using the computer program 'WENNER'/2/. In Survey #2 in the park area (Table 2), the low readings at 1 and 2 m spacings may be due to the anomalous surface layers such as top soil and sod. The reading at the 20 m spacing is probably low due to the close proximity of the probes to the fence. Therefore, a uniform resistivity of 92 Ω.m was interpreted as an average of the measured apparent resistivities at the probe spacings of 5 and 10 m. Table 5 compares the two-layer model parameters for each location and Tables 1 to 4 list the modelled apparent resistivities along with the measured values. Figures 2 to 4 show the plots of the field data and the corresponding model curve (Model A) for each location.

**TABLE 5**
**FITTED TWO-LAYER MODEL PARAMETERS FROM WENNER DATA**

| Survey No. | | $\rho_1$ (Ω.m) | d (m) | $\rho_2$ (Ω.m) |
|---|---|---|---|---|
| 1 | (A) | 520 | 1.2 | 104 |
| | (B) | 589 | 1.0 | 100 |
| 3 | (A) | 260 | 1.0 | 33 |
| | (B) | 270 | 0.9 | 33 |
| 4 & 5 * | (A) | 360 | 2.2 | 90 |
| | (B) | 367 | 2.3 | 90 |

Model (A) using graphical method
Model (B) using computer program
* Based on average data

## 5.0 DISCUSSION OF RESULTS

(a) All three surveys on the railway embankment yielded consistent apparent resistivities at small probe spacings. The readings at the large probe spacings may have been influenced by the proximity of the fences and were ignored in the interpretation. Therefore, the two-layer soil models interpreted from the measured data at both locations generally represents the embankment. Here, the high resistivity top layer is consistent with the observed surface gravel at the site. The bottom layer resistivity probably represents the embankment fill below the surface gravel. The two-layer models from the surveys on the embankment may be used for an estimate of the grounding system parameters locally at the embankment such as the junction grid resistance.

(b) In Survey #3 on the level ground below the embankment, the measured resistivity at the 1 m spacing is high mainly due to the surface gravel as observed at the site. The reading at 5 m probe spacing may be low due to some unknown underground metallic objects and the readings at spacings of 10 - 50 m may have been influenced by the close proximity of the probes to the fences. Therefore, the two-layer soil model interpreted from the data in Survey #3 may be lower than the actual soil structure at the site and a design based on this model may not be conservative.

(c) The locally uniform resistivity of 92 Ω.m interpreted from Survey #2 on the park is consistent with the bottom layer resistivities obtained from the surveys on the embankment. Larger probe spacings would probably include the effects of an urban mesh of buried conductors such as pipes. While the equivalent resistivity in the city may be lower than that measured, 92 Ω.m may be used in estimating the earth return impedances of cable pipes and skywires to give a conservative design.

(d) The two-layer interpretation of the Wenner data using both the graphical method and the 'WENNER' computer program yielded consistent results. The computer program was found convenient but the graphical method gave physical insight and made bad data more recognizable.

## 6.0 CONCLUSIONS

(a) A two-layer interpretation of the measured Wenner data yielded the following results for the railway embankment.

| | |
|---|---|
| Top layer (gravel) resistivity | = 360 - 589 Ω.m |
| Thickness of top layer | = 1.0 - 2.3 m |
| Bottom layer resistivity | = 90 - 104 Ω.m |

(b) The bottom layer resistivity does not include the effects of an urban mesh of buried conductors such as pipes which would reduce the resistivity value.

## 7.0 RECOMMENDATIONS

(a) The following two-layer soil model based on the average measured results may be used for estimating the junction grid resistance.

| | |
|---|---|
| Top layer resistivity | = 460 Ω.m |
| Thickness of top layer | = 1.5 m |
| Bottom layer resistivity | = 92 Ω.m |

(b) A uniform resistivity of 92 Ω.m may be used for estimating the earth return impedances of the cable pipes and skywires and the transfer impedance to rails.

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**REFERENCES**


1. Ontario Hydro, Guide for Grounding, 1983 Revision.

2. Computer program "WENNER" to analyze earth resistivity data obtained using wenner method, developed by Mr. R.G. Irvine of Telecommunication Department, based on CEA Report #143 T 250.

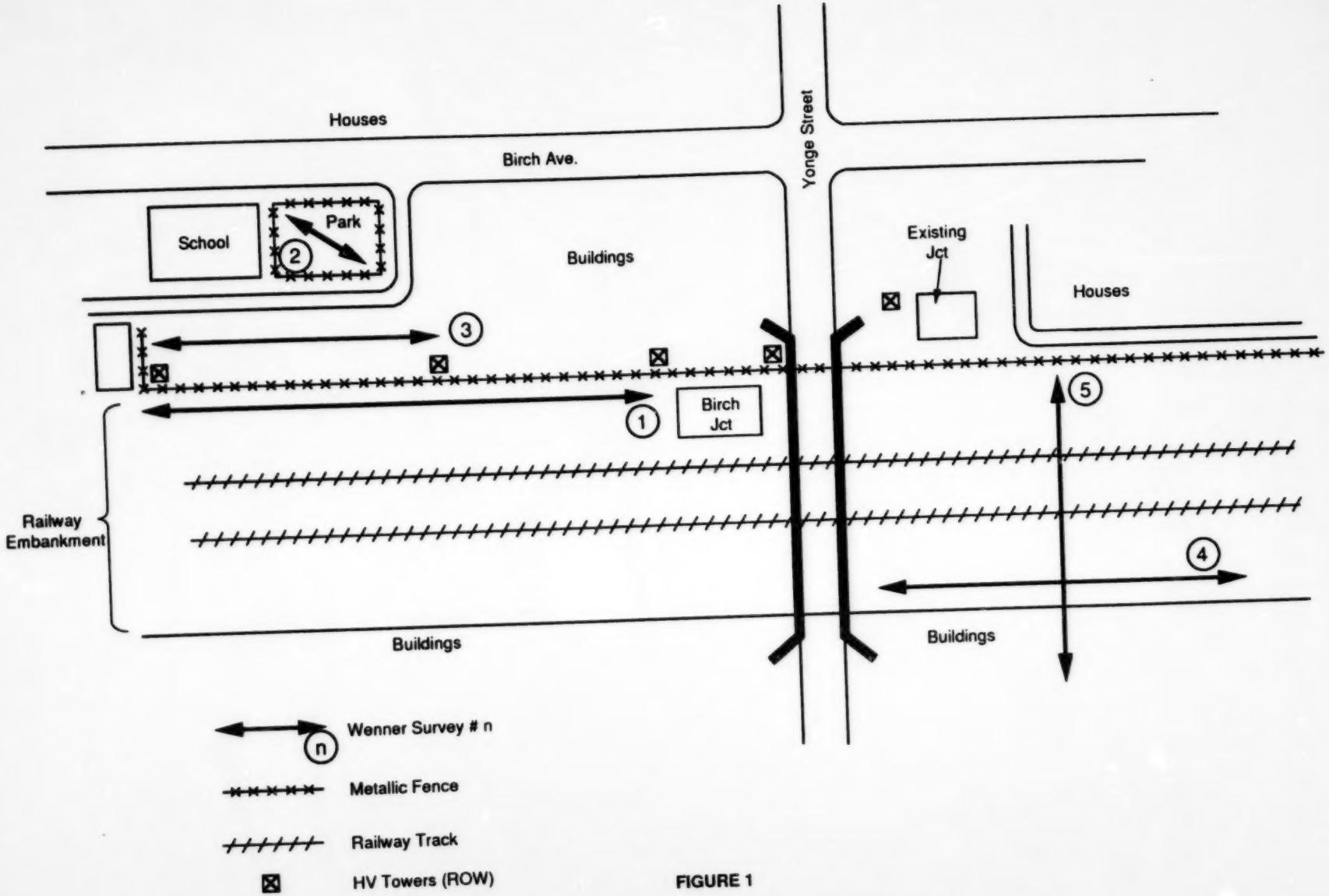


FIGURE 1

BIRCH JUNCTION LAYOUT WITH RESPECT TO SOIL RESISTIVITY SURVEYS

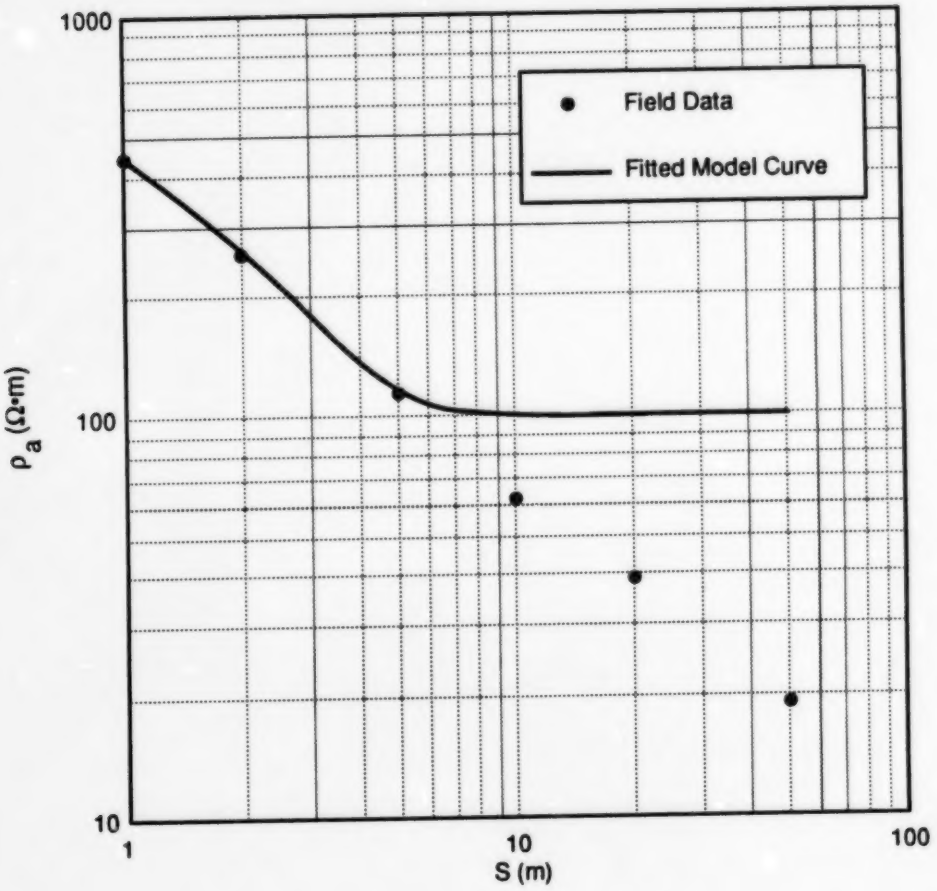


**FIGURE 2**

**BIRCH JUNCTION WENNER SURVEY #1**
**APPARENT SOIL RESISTIVITY MODEL**

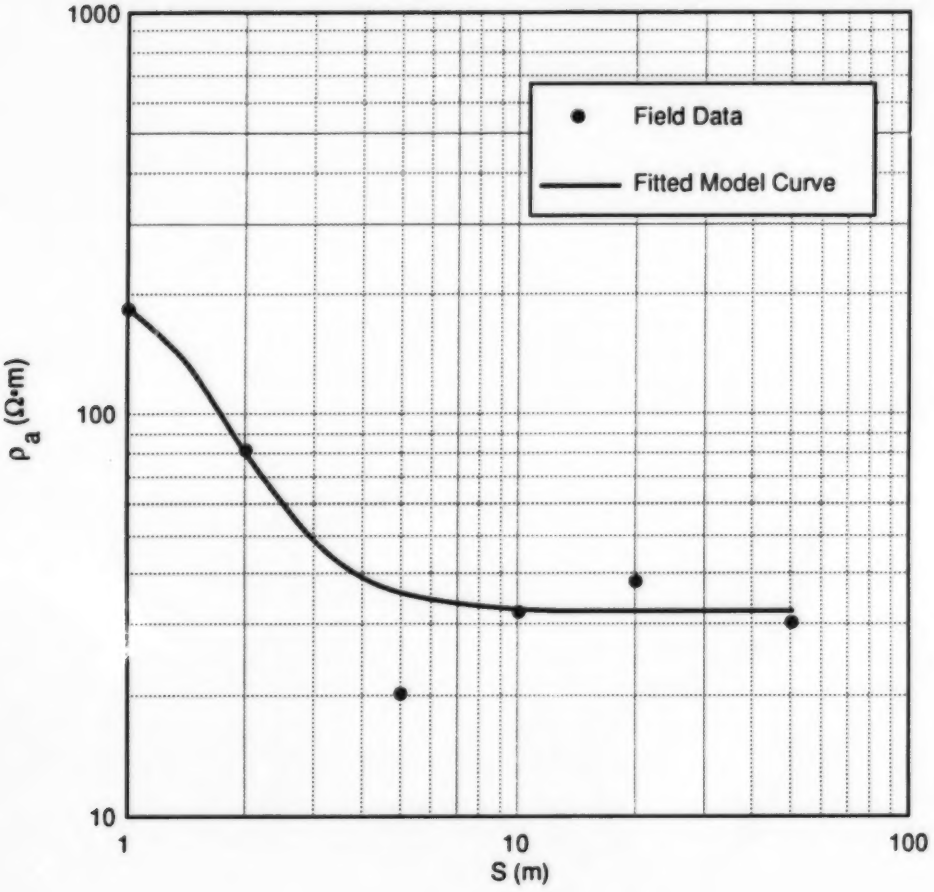


**FIGURE 3**

**BIRCH JUNCTION WENNER SURVEY #3**
**APPARENT RESISTIVITY MODEL**

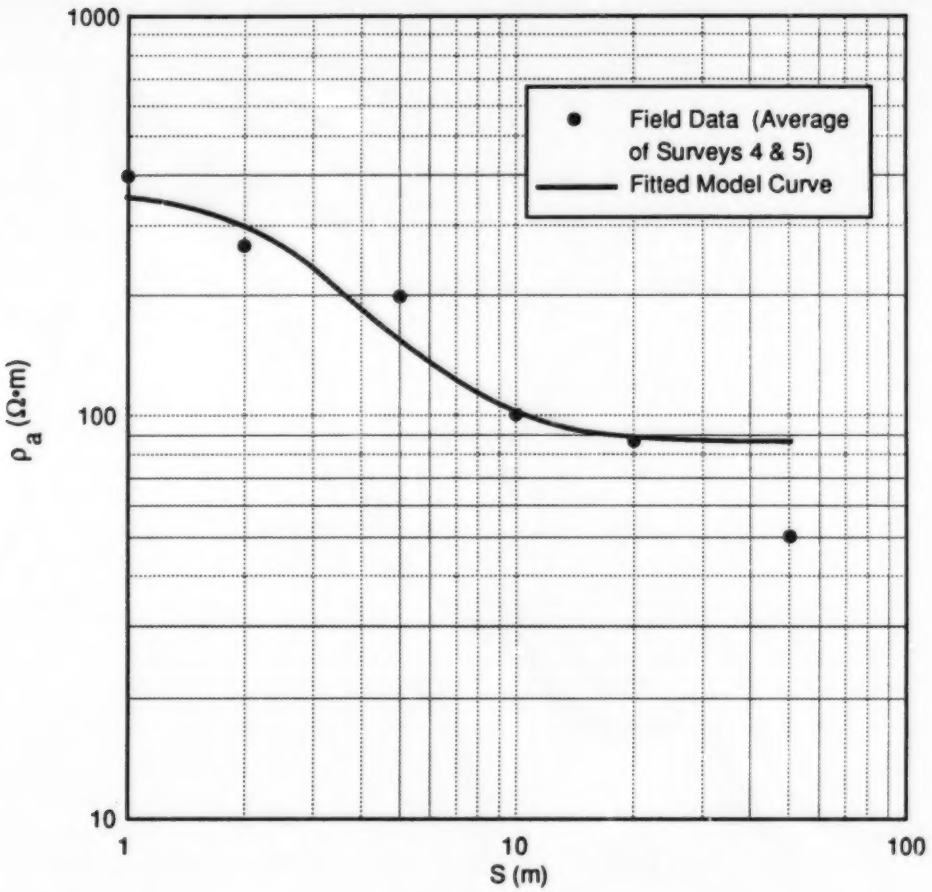


**FIGURE 4**

**BIRCH JUNCTION WENNER SURVEYS #4 AND #5**
**APPARENT RESISTIVITY MODEL**